Analysis of the Co-benefits of Greenhouse Gas Abatement for Global and US Air Quality under Future Climate Scenarios

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Connections Between Air Pollution and Climate Change

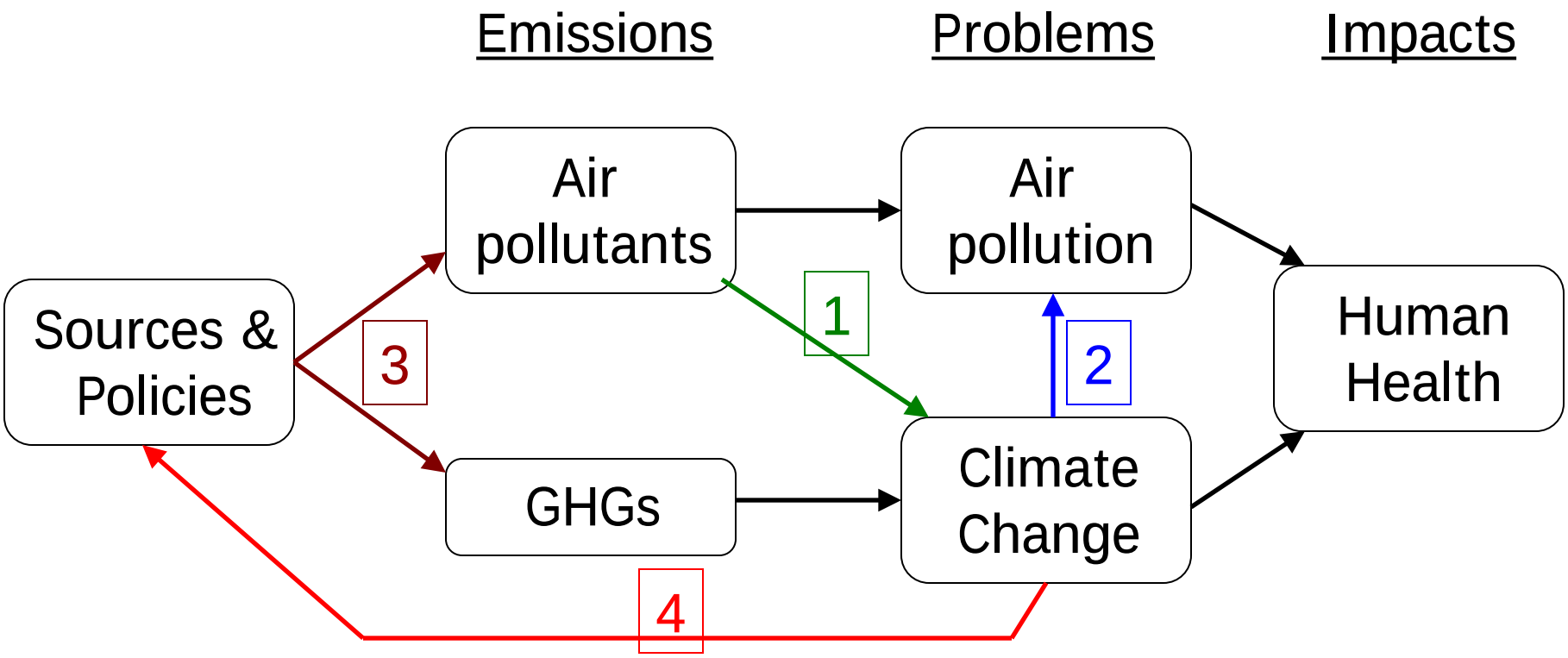
1) Several air pollutants affect climate
   - Ozone (O_3) is a greenhouse gas (GHG)
   - Aerosols scatter and absorb sunlight, and affect clouds.

2) Changes in climate may affect air quality (of O_3, PM, or other pollutants).

3) Sources of air pollutants and GHGs are shared – fossil fuel combustion.

4) Climate change may influence demands for energy, and therefore emissions.

Connections Between Air Pollution and Climate Change



Big Question: How can we plan to address air pollution and climate change in a coordinated way?

Co-benefits - Two Lines of Research

Co-benefits of GHG Mitigation on Air Quality (immediate and local)

- Air quality and health co-benefits shown to be substantial compared to GHG abatement costs.
- Most studies have focused locally or regionally.
- Tend not to analyze future scenarios.
- None has been global using an atmospheric model.

(Ekins, 1996; WGPHFFC, 1997; Cifuentes et al., 2001; Burtraw et al., 2003; Aunan et al., 2003; van Vuuren et al., 2006; Bell et al., 2008)

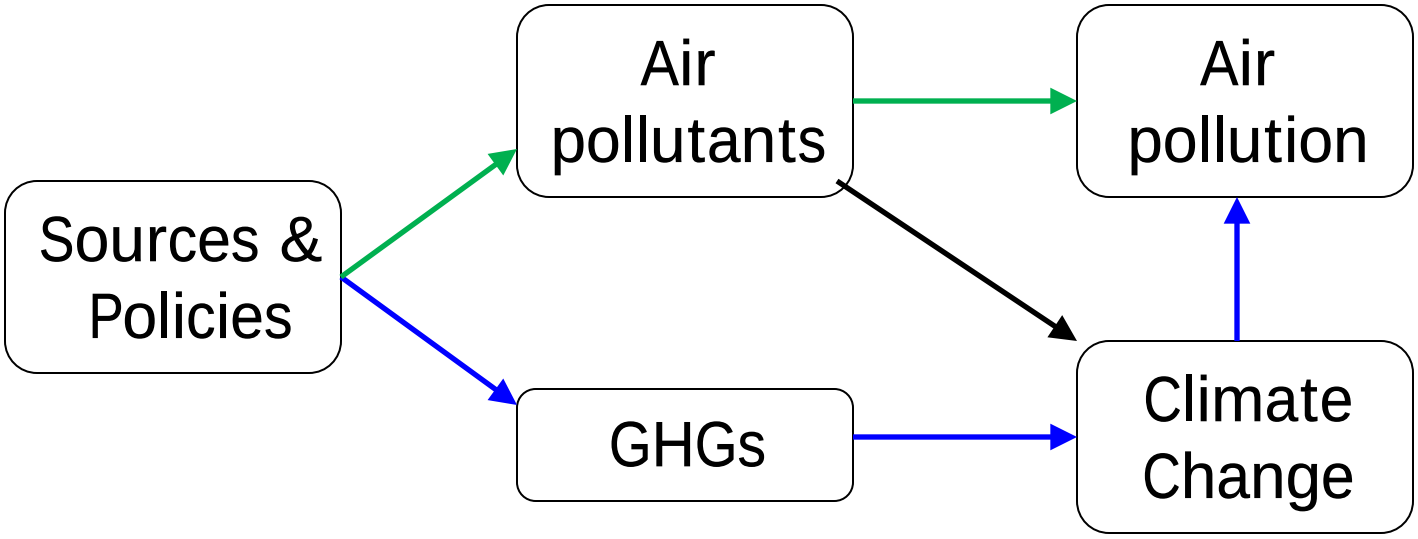
Climate Change Affecting Future Air Quality (future and global)

- Climate change shown to increase O_3 in US; effects on PM less clear.
- Emphasis on meteorological downscaling.
- Tend not to analyze future emissions scenarios.
- Few studies present health, economic damages; need benefits of GHG action.

(Mickley et al., 2004; Hogrefe et al., 2004; Hauglustaine et al., 2005; Tagaris et al., 2007; Liao et al., 2007; Wu et al., 2008; Weaver et al., 2009; Jacob and Winner, 2009; Fiore et al., 2012)

Two Mechanisms of Co-benefits

1) Immediate and Local



2) Long-Term and Global

Objectives

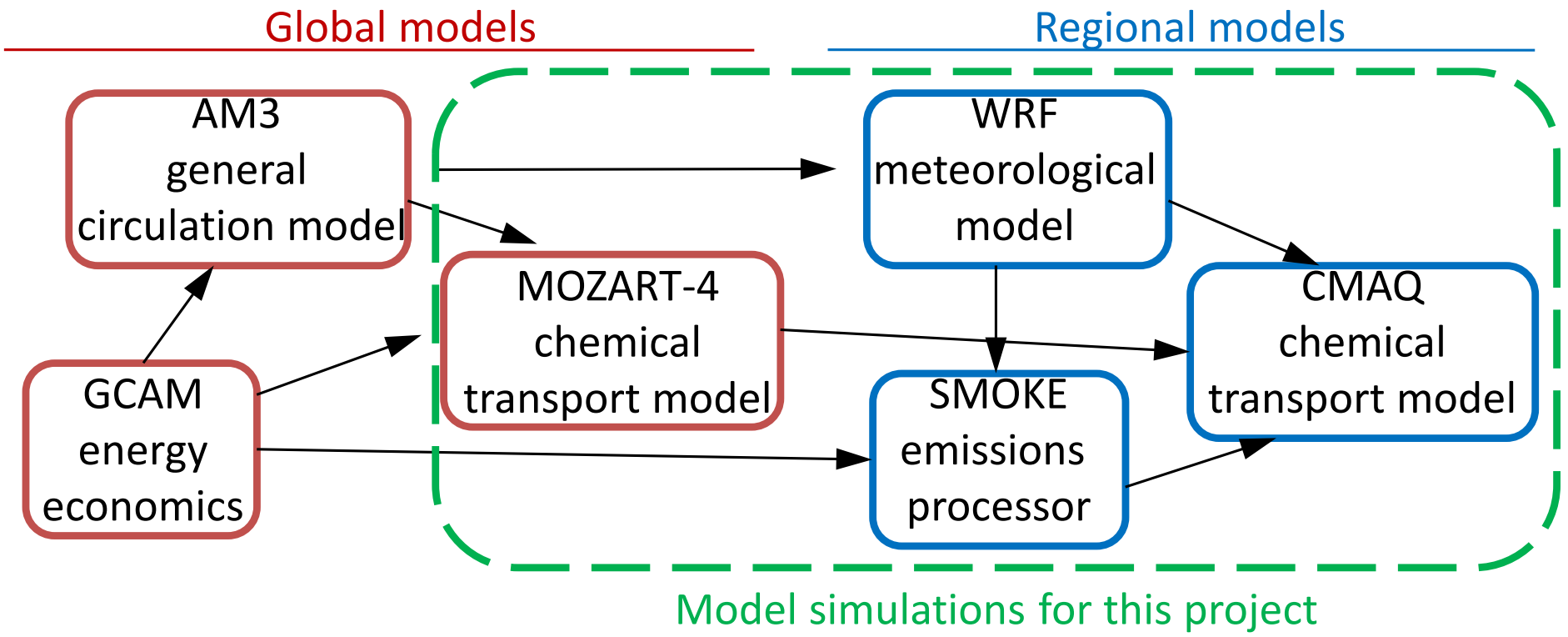
Evaluate the air quality co-benefits of actions to reduce GHG emissions, globally and in the US, in future scenarios to 2050.

1) Evaluate the effects of global methane mitigation on ozone air quality in the US at fine resolution.

2) Evaluate the co-benefits of global GHG mitigation on ozone and PM air quality, globally and in the US, via two mechanisms:

- by reducing co-emitted air pollutants.
- by slowing climate change and its effects on air quality.

System of Global & Regional Models

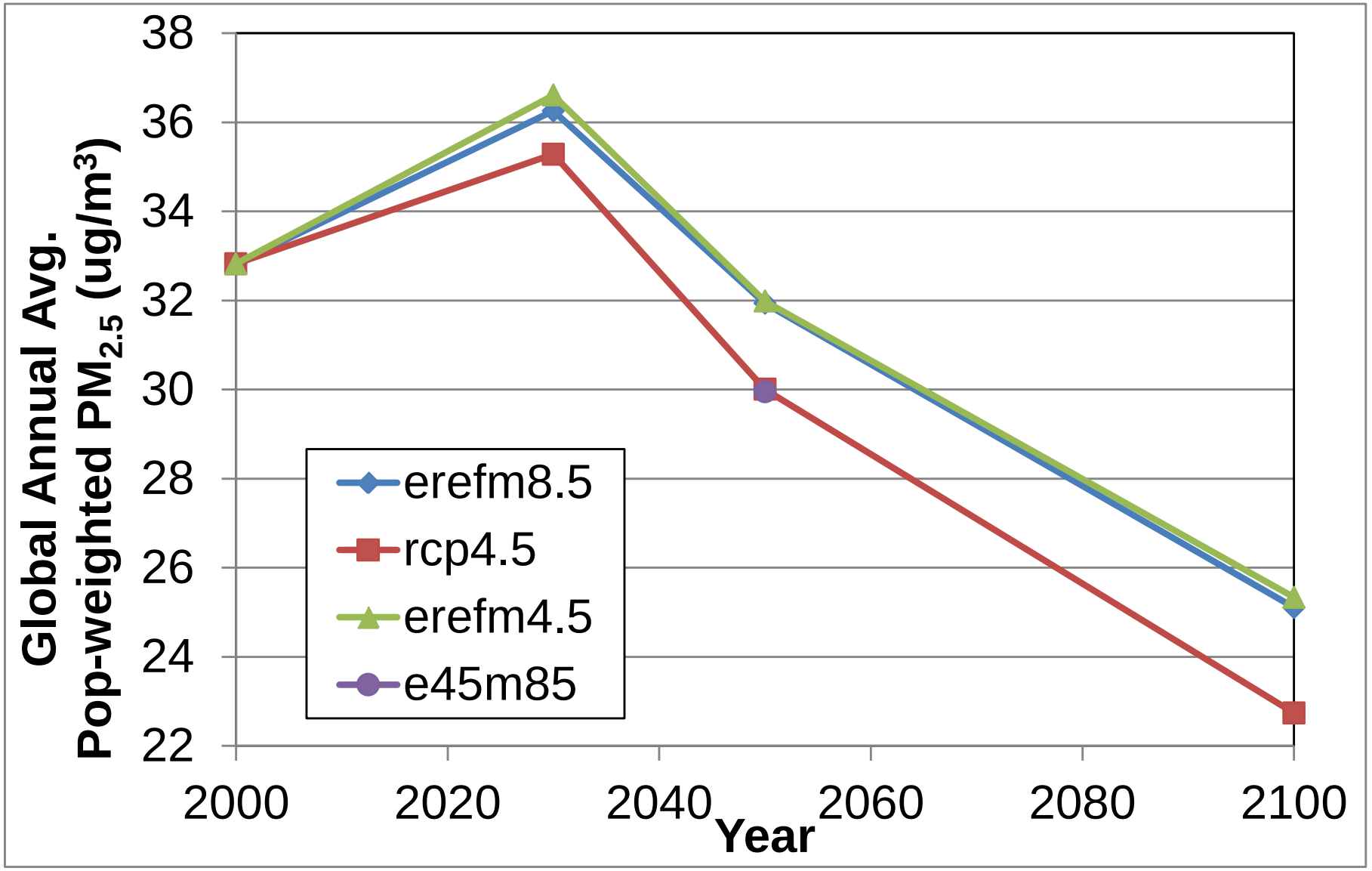


Approach

Years	Emissions GCAM	Meteorology GFDL AM3	Name
2000	2000	2000	2000
2030, 2050, 2100	GCAM Reference	RCP8.5	erefm85
	RCP4.5	RCP4.5	rcp45
	GCAM Reference	RCP4.5	erefm45

- Use the GCAM reference for emissions rather than RCP8.5 for consistency with RCP4.5.
- Simulations conducted in MOZART-4 global chemical transport model.
  - 5 meteorology years for each case.
  - Fixed methane concentrations estimated by MAGICC.
  - 2° x 2.5° horizontal resolution.

Results – $PM_{2.5}$ Concentration

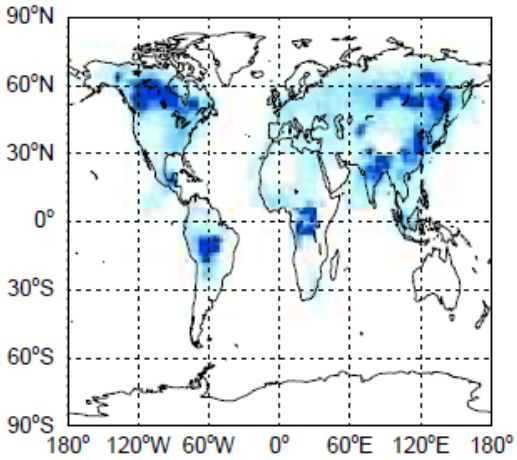


Results – $PM_{2.5}$ Concentration

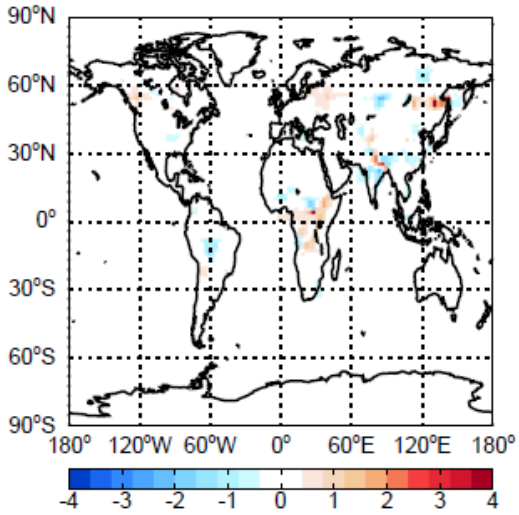
Annual average $PM_{2.5}$

2050

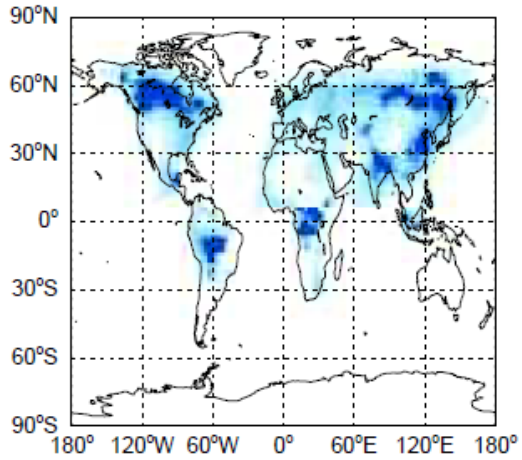
Total co-benefit



#2 Meteorology

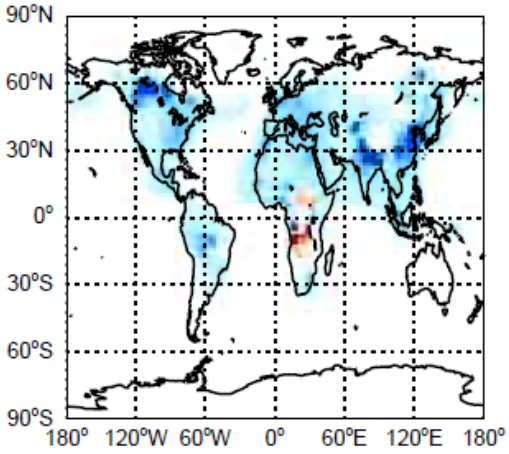


#1 Emissions



2100

Total co-benefit



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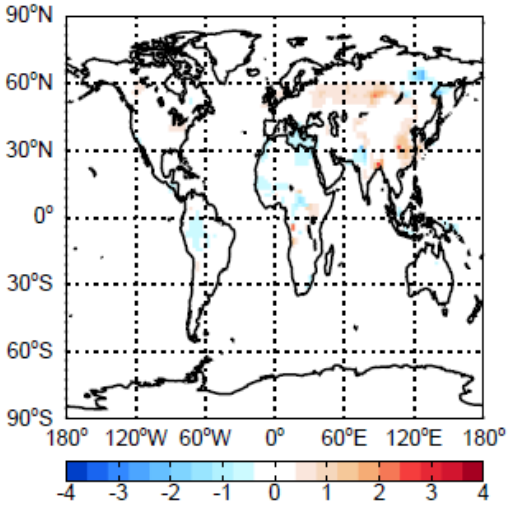

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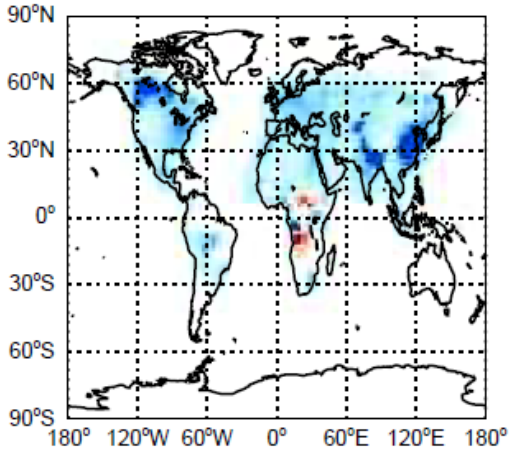
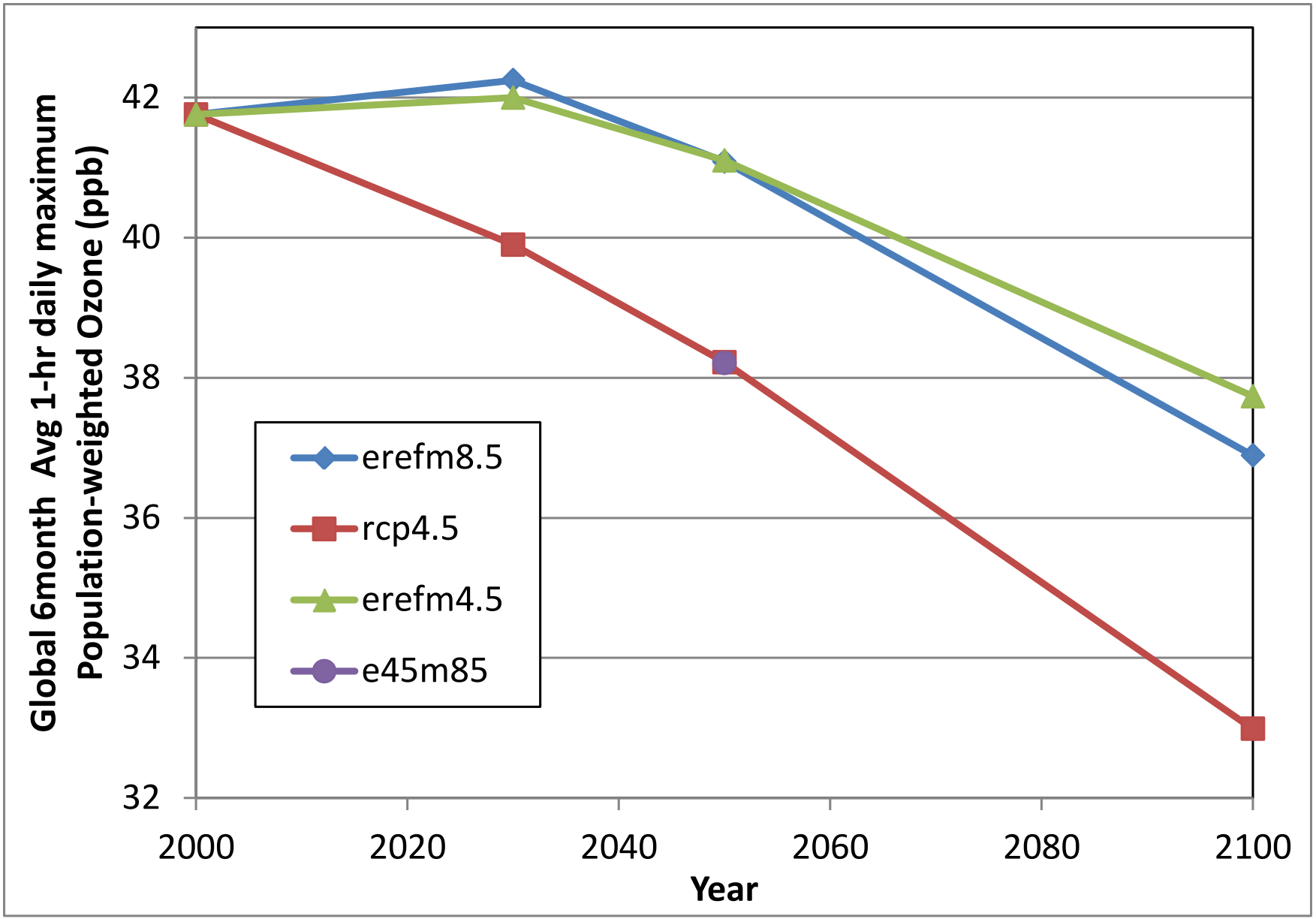


Results – Ozone Concentration

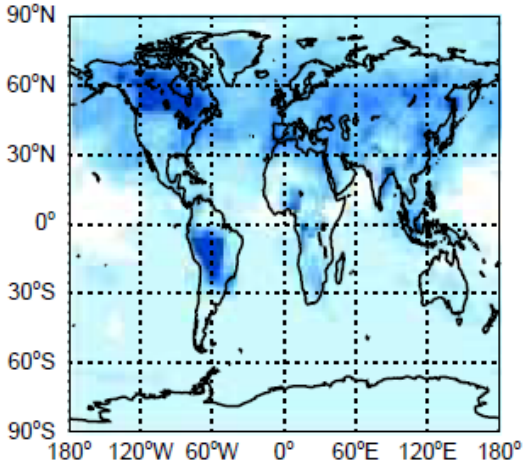


Results – Ozone Concentration

Max. 6 month average of 1 hr. daily max ozone

2050

Total co-benefit



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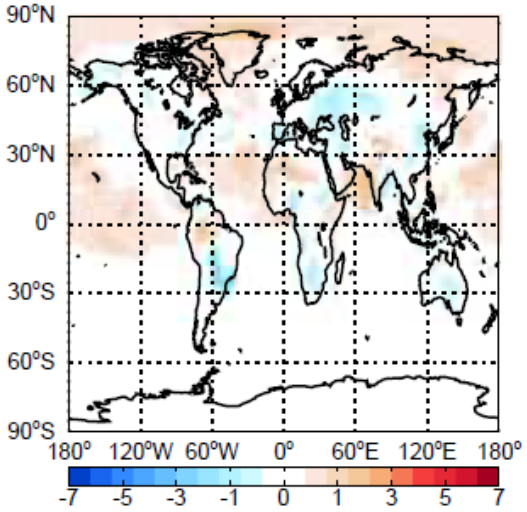

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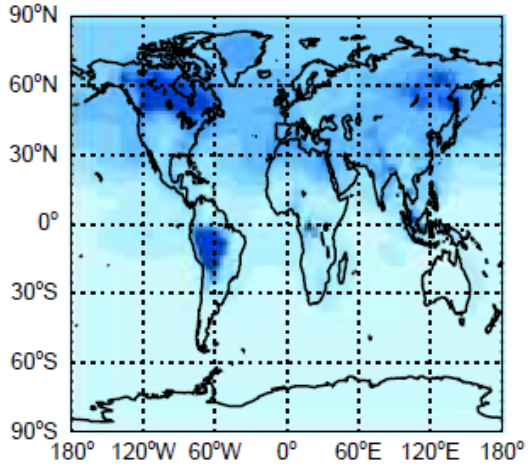
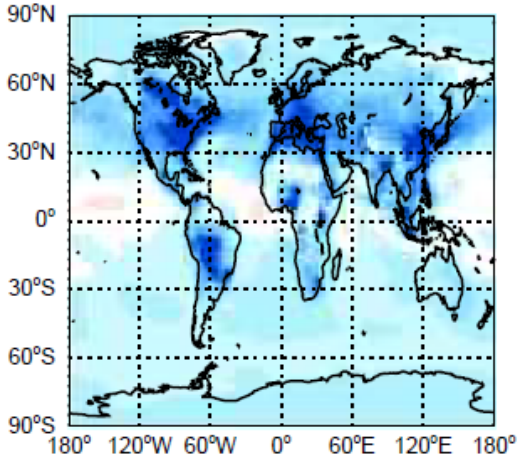


2100

Total co-benefit



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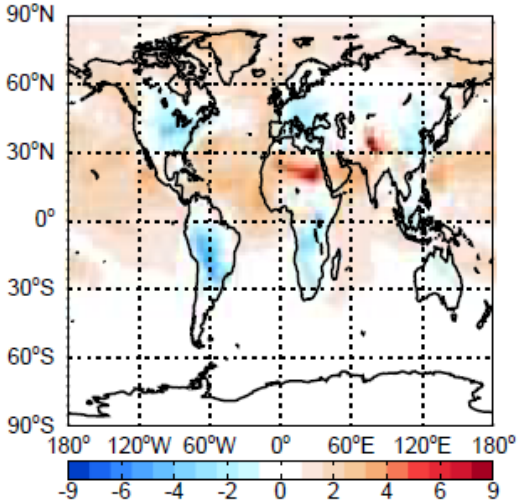

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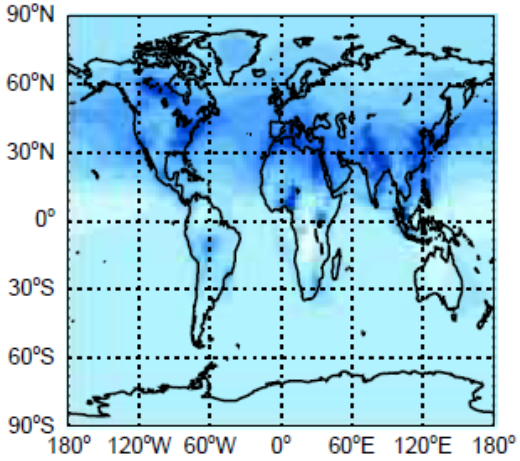
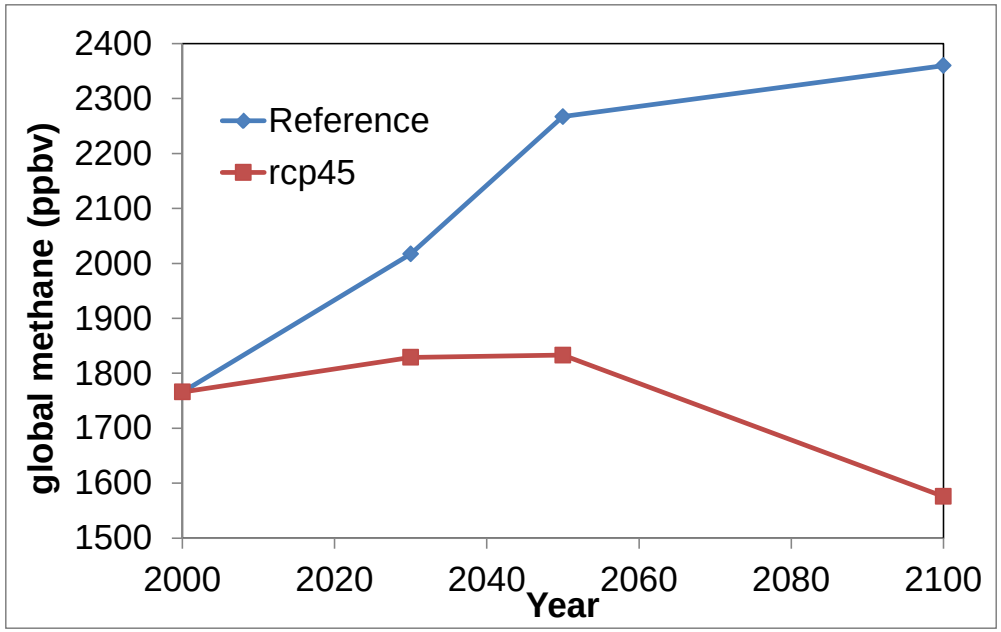
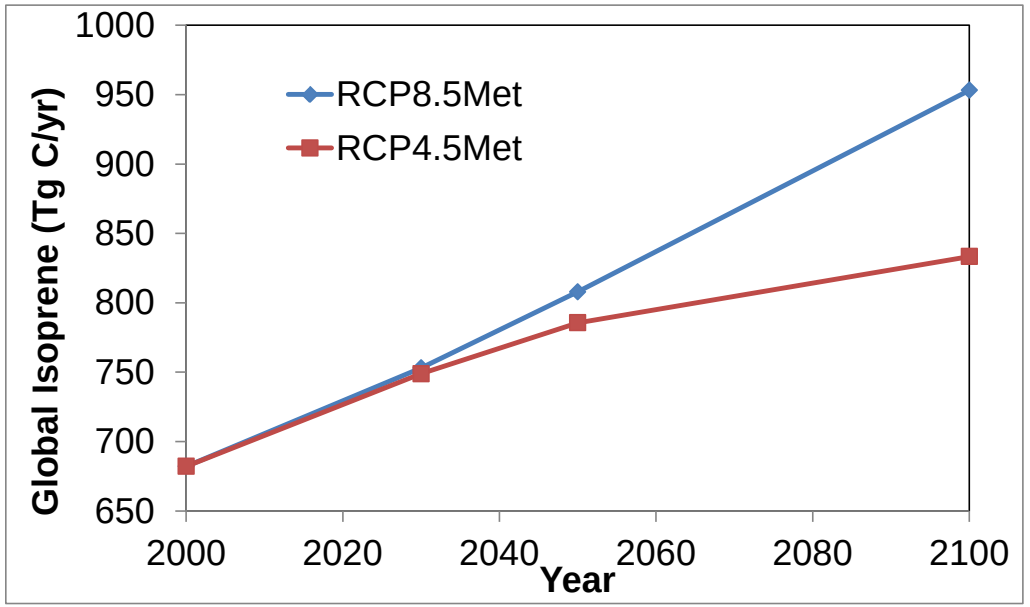


Drivers for Ozone Concentration



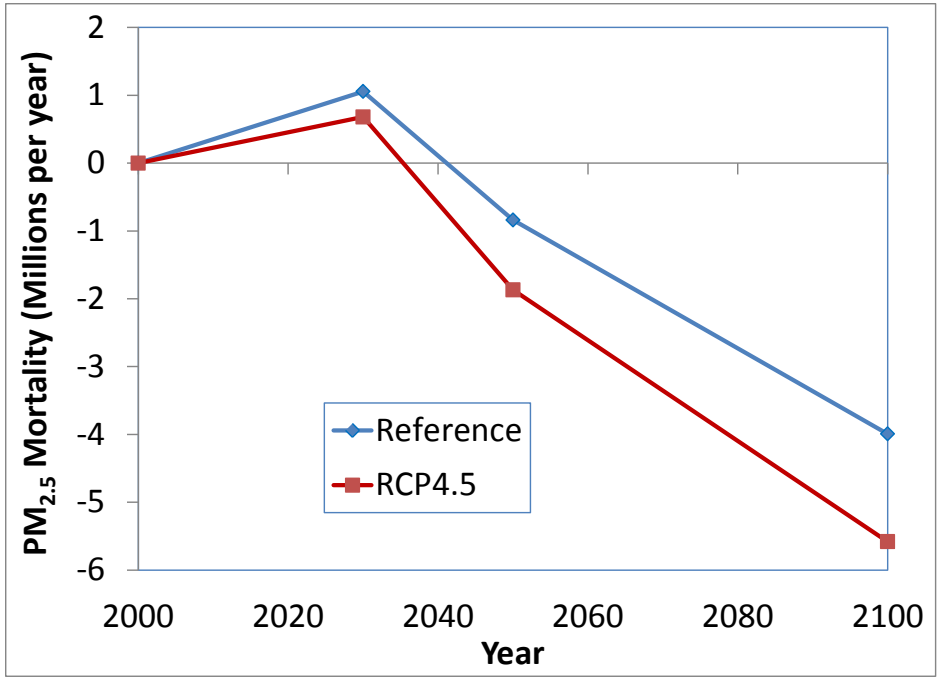
Methane Concentration

Global Isoprene Emissions estimated by MEGAN, varies with meteorology

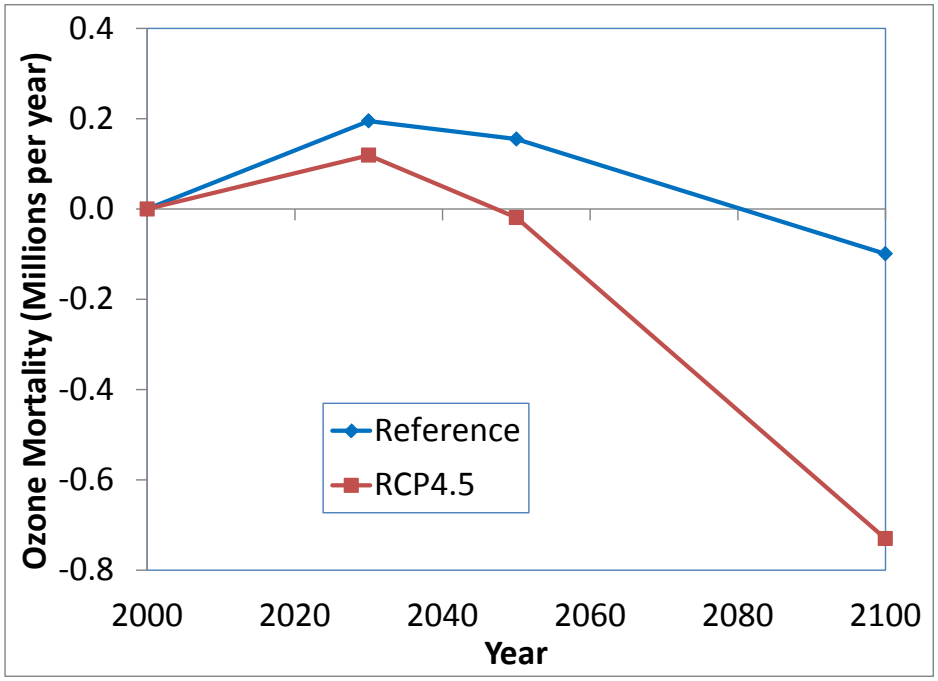


Results – Global Premature Mortality

$PM_{2.5}$ Cardiopulmonary Mortality



Ozone Cardiovascular Mortality



$PM_{2.5}$ co-benefits –

2030: 0.4

2050: 1.0

2100: 1.3 million deaths / yr

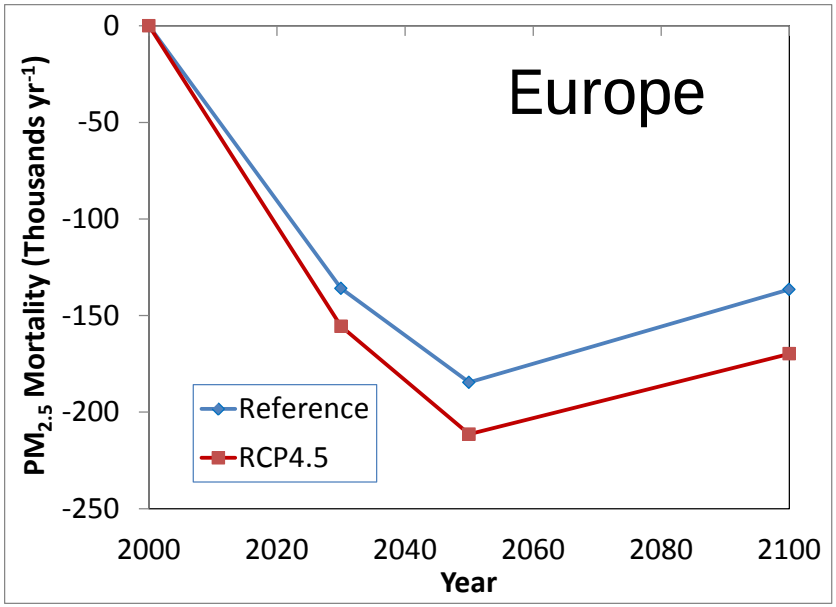
Ozone co-benefits –

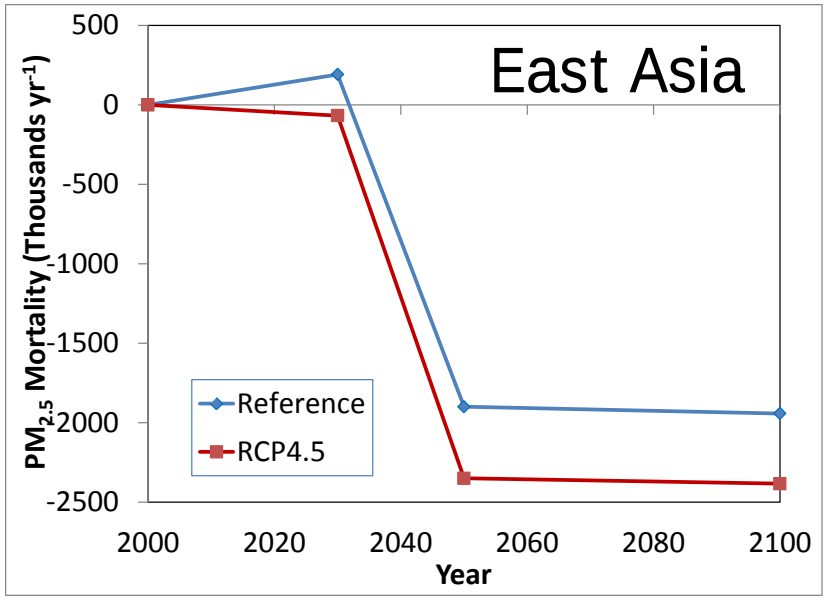
2030: 0.1

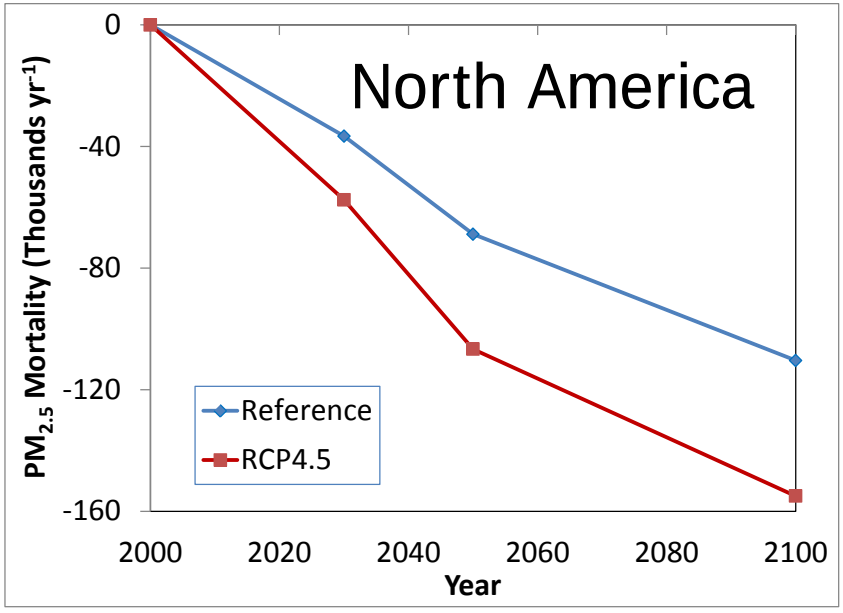
2050: 0.2

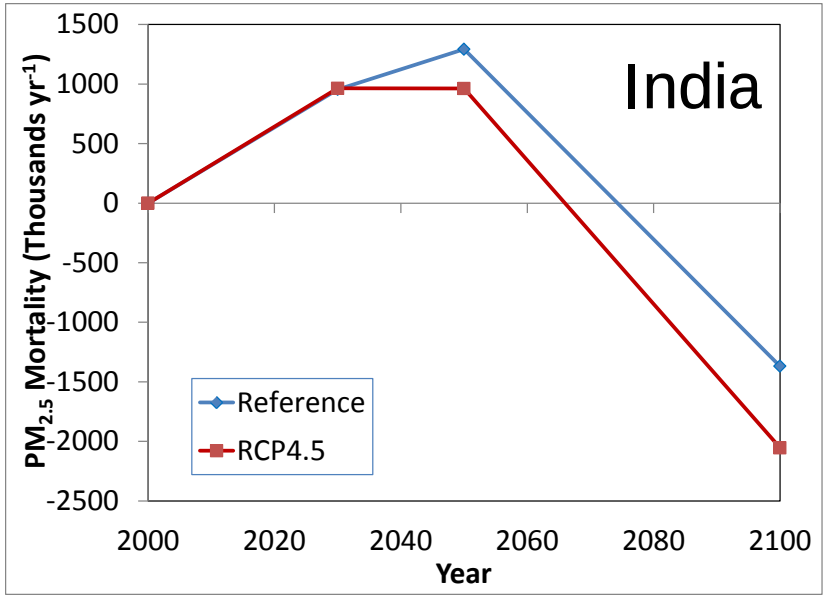
2100: 0.6 million deaths / yr

Results – Regional $PM_{2.5}$ Mortality









Work Underway: Meteorological Downscaling to US

1) Effects of global methane mitigation on ozone air quality in the US at fine resolution.

2) Downscaling of Future RCP8.5 and RCP4.5 meteorology and analysis of air quality in US.
   - Assessment of air quality co-benefits from US emissions alone.

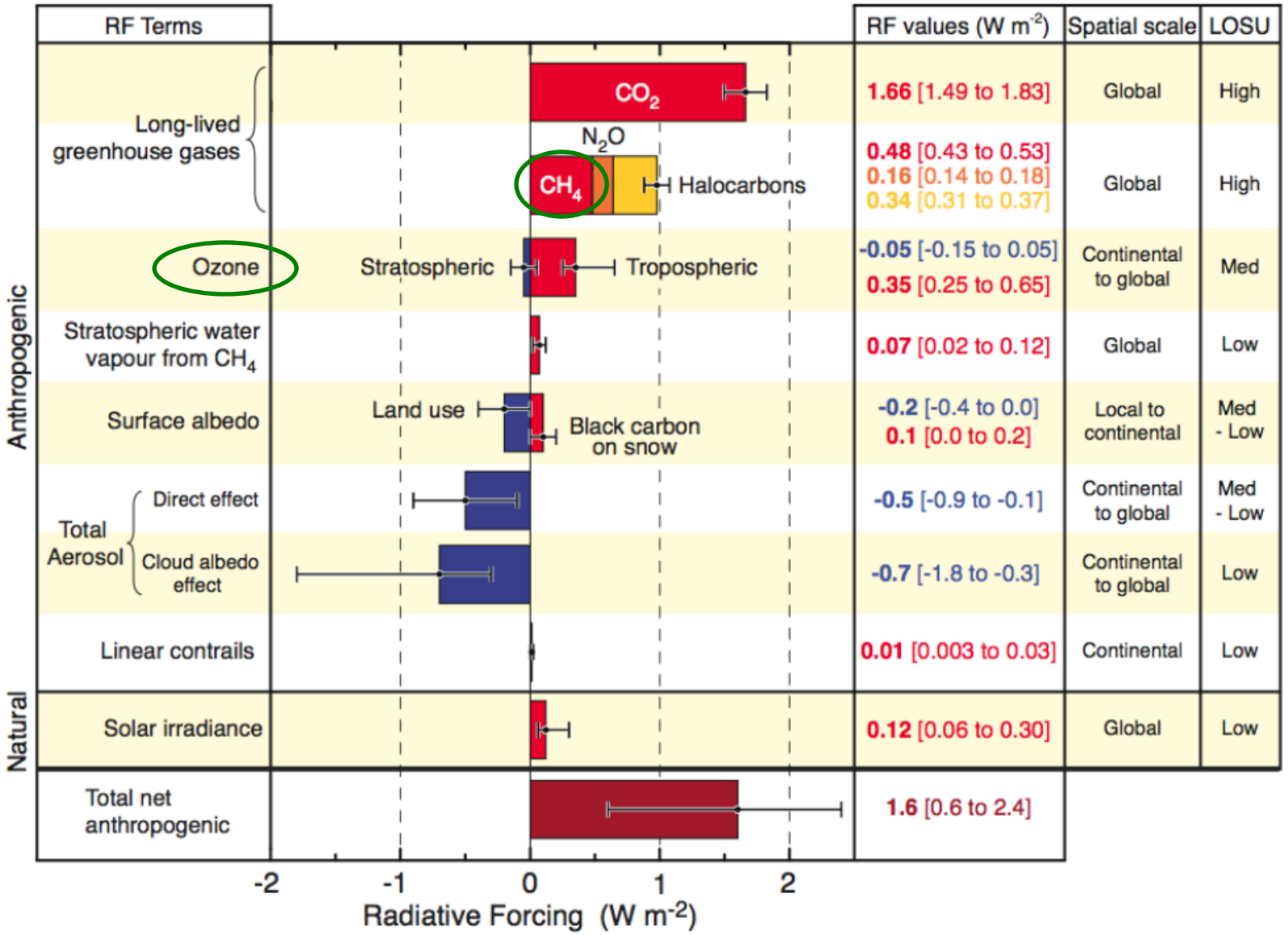
WRF - SMOKE - CMAQ

Co-benefits: preliminary conclusions

- Air quality co-benefits of reducing GHGs are on the order of 1 million avoided deaths per year, globally, in 2050 and 2100.
- The reference scenario assumes air pollution decreases to 2100 – this reduces co-benefits of GHG mitigation.
- The direct co-benefits from air pollutant emission reductions exceed those via slowing climate change.
- Forthcoming:
  - Assessment of $PM_{2.5}$ lung cancer mortality.
  - Uncertainty ranges on health.
  - Comparison of monetized health benefits with GHG control costs.
  - More complete analysis of regional air quality changes.

Radiative Forcing of Climate, 1750-Present

Important Contributions from Methane and Ozone



Connections Between Air Pollution and Climate Change